REMARKS

This amendment is responsive to the first official action, Paper No. 4.

As to the disclosure, a requirement was made in the action to label Fig. 7 as prior art, consistent with the specification. A more descriptive title was required. References to numbered claims were considered informal.

As to the claims, claims 2 and 3 were considered indefinite for reasons of grammar. Claims 1-3 were rejected as anticipated by US Pat. 5,808,893 – Pugh.

Applicant submits a proposed drawing correction including an annotated print and a clean print to comply with the drawing requirement.

The title is changed to - - Numerical Control Method Including Inserting Time Variable into Spatial Polynomial for Controlling Object Motion - -.

The specification is amended to eliminate the references to numbered claims, referring instead to the invention or to embodiments thereof. Additionally, applicant has reviewed and revise the specification for idiomatic and grammatical concerns. No new matter is presented.

The claims have been amended to more particularly and distinctly define the subject matter. The examiner's suggestions regarding changing "deriving" to - - taking the derivative - - have been adopted. Applicant also submits additional claims (within the number for which fees have already been paid) using the term - - differentiating - -.

The claims as amended are definite. The disclosure is in proper form.

Applicant requests reconsideration of the rejection under 35 U.S.C. §102 based on Pugh (US 5,808,893). Pugh does not anticipate the invention claimed as a whole. Nor does Pugh render obvious the invention claimed as a whole.

It is an aspect of the invention that the locus of the object to be controlled is initially defined using a spatial polynomial function to approximate the programmed contour or path to be followed by the object. The spatial function may relate to a

surface to be formed, for example, during machining a workpiece. When a workpiece is machined, one or both of the cutting head and the workpiece typically are moved.

The spatial function that defines the surface or path locus over which the object is to pass (such as a laser cutting head) is first problem, and the motion of the object, namely the speed and direction of the object, is a next problem.

For example, a line on a plane surface can be defined by the relationship of two variables, such as X and Y, or a surface in a space can be defined by the relationship of three variables. There is no time aspect to a path in space.

According to applicant's invention, the locus or path of the object in the working space first is defined by a relationship of position variables, independent of time, to provide a spatial polynomial function approximating the object path.

After that, a time function is imposed on the polynomial approximating the path, to produce a motion function. According to the invention, the motion function is based on the spatial polynomial approximating the path in space, because one or more of the position variables in the spatial polynomial that approximates the spatial path, is replaced by a time function. This converts the spatial approximation into an equation expressing motion.

As discussed in the prior art section of applicant's specification, it is known to control the position of an object by moving the object in incremental steps according to a sampling interval. A numerical control machine that seeks to move an object over a path determines the nominally correct position of the object during a given step or sample interval, collects sample data representing the actual position of the object (such as the position of a shaft angle encoder), and applies force to move the object toward the nominally correct position if there is a positioning error.

A problem with such a feedback control occurs, particularly when the programmed path of the object suddenly diverges, because the feedback control is always responding in the current sampling cycle to the error sensed in a previous cycle. The control position tends to overshoot.

It is possible to cause a conventional feedback control to seek to follow a programmed path. It is also possible to program a path so as to take into account

velocity and acceleration. Applicant's Fig. 7 shows a conventional feedback control and the feedback/feed-forward control blocks that cause it to function, in an embodiment that has these aspects. However, the known control blocks for reading out a sequence of preprogrammed nominal displacement values, velocities and/or acceleration values do not solve the problem of initially determining the values of the inputs to be applied. According to the prior art, the contour is an arbitrary sequence that is somehow already known. The programmer may determine from planning or from trial and error that a particular acceleration or velocity is desirable at a particular time. However, the prior art does not disclose or suggest approximating a spatial path with a polynomial, inserting a time function into the polynomial approximation, and distributing that time function over several axes to provide multi-axis control values for displacement, velocity, acceleration and jerk.

The programmer according to the prior art has to compose and feed into a controller a sequence of desired displacement and motion values for successive control steps. The programmer according to applicant's invention has to feed in a path that is approximated by a spatial polynomial, and the polynomial, by inserting a time variable, provides the displacement and motion values mathematically, namely displacement, velocity, acceleration and jerk.

The examiner has rejected the claims as anticipated by Pugh, which teaches that it is possible to determine velocity, acceleration and jerk values for a multi-axis control by repeated differentiating a function of displacement versus time. However it is a simple matter, if one already has a function for displacement versus time, to produce values of velocity, acceleration and jerk. These are by definition the first, second and third derivative of the displacement function. By complying with a function stating displacement versus time, one will inherently produce the values for velocity, acceleration and jerk that are the first, second and third derivative of the displacement function.

But the issue is where the displacement function is obtained, not that its derivatives by time increment equate to velocity, acceleration and jerk.

Applicant's invention claimed as a whole incorporates the idea of a positioning control that can determine its own motion parameters. Applicant's invention entails the processing steps of approximating a shape using a wholly spatial polynomial function, at least for successive segments defining the object path. The spatial polynomial is converted into a motion polynomial. From that point, the motion parameters are defined and available by mathematically taking derivatives.

Inasmuch as applicant's invention determines motion parameters (namely by inserting a time variable into a spatial polynomial approximation), one can determine and prepare the values of the derivatives of the function beforehand, and employ in the positioning control the necessary velocity, acceleration and jerk to achieve the spatial polynomial path. The invention can predict the changes in velocity, acceleration and jerk that will cause the object to follow a displacement path. The invention thereby reduces or eliminates the need to control in the present substantially on the error between a desired value and the actual sensed value of a parameter in the past.

The prior art of record does not teach or suggest applicant's invention claimed as a whole. In Pugh (US 5,808,893), a time parameter polynomial $p=x(t)$ is mentioned and velocity and acceleration are obtained. However, there is no mention of approximating a path with a spatial polynomial as an initial step, and substituting a spatial variable for a corresponding time function. Mathematically deriving velocity and acceleration from an already-available time parameter polynomial is apparent. The real problem is how to obtain the time parameter polynomial $p=x(t)$ and relate it to the locus or path of the object. The Pugh reference does not supply the necessary step of providing a spatial polynomial approximating a path and then substituting a time variable for one or more spatial variables.
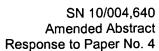
Assuming that the desired locus it so approximate some arbitrary path in space, such as a spline function, for example, there is no inherent parameter involving time. The conventional technique is to move stepwise along the axes, i.e., immediately converting the spatial polynomial to movements along each of the respective axes of control in the joint space. The conventional technique lacks any suggestion of first converting the spatial polynomial into a time parameter type polynomial as in the

invention claimed. However, it is the polynomial approximation in applicant's invention, converted to a time function, that allows the differentiation to produce not only a nominal displacement target during each sampling time, but also nominal velocity, acceleration and jerk values for each sampling time. Moreover, the differentiations for velocity, acceleration and jerk need not relate to and be computed only from the previous and current displacement values. According to the invention, the velocity, acceleration and jerk also can be computed on the basis of the future displacement values. This beneficial aspect results from the initial approximation of the path as a spatial polynomial and the conversion of the spatial polynomial to a time polynomial from which the first, second and third derivates can be taken at any arbitrary point in time.

The invention comprises approximating the path by a spatial polynomial, converting the spatial polynomial into a time parameter polynomial and distributing the motion over the respective control axes in the joint space using commands derived from the time-imposed initial polynomial that approximates the spatial path. These features are not disclosed in the cited reference to Pugh. The Pugh reference fails to meet the invention claimed as a whole.

By means of applicant's claimed invention, the velocity, the acceleration and the jerk of the end of the torch (the working end of the tool) can be obtained by differentiating the time parameter polynomial. There is less need to respond in a given sample to an error detected in a previous cycle, because differentiation of the time polynomial provides a sort of preview control that applies the changes that will direct the tool toward the next displacement sample, as determined mathematically from the polynomial approximation of the path.

The respective control axes are driven on the basis of the differentiated control parameters, such as the velocity and the acceleration, obtained from the approximated path. The differentiated parameters provide a preview control responsive not only to feedback controlled reduction of error in previous cycles, but also to move in the direction of a next sample even if the next sample represented in the polynomial is an abrupt change of direction from the previous directions of progress.

The Pugh cited reference fails to disclose such points and does not meet the invention claimed as a whole.

Every effort has been made to present the subject matter of the application in proper form, to particularly and distinctly define the subject matter regarded as the invention and to demonstrate that the subject matter claimed as a whole is properly patentable over the prior art. The disclosure and claims as amended are in condition for allowance. Reconsideration and allowance are requested.

Respectfully submitted,

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